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Anatomical parameters of the Rouviere's sulcus for laparoscopic cholecystectomy

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SUMMARY

Rouviere's sulcus (RS) is a structure on the posterior surface of the liver that appears as a transverse cleft extending from the caudate process to the right lobe. RS lies exactly in the plane of the common bile duct, giving it important clinical applications in laparoscopic cholecystectomy, partial hepatectomy and other hepatobiliary operations. This study aimed to describe the morphology of RS, as well as to provide measurements of the length, breadth and width of the sulcus.

The present study included the analysis of 75 formalin-fixed adult livers. RS was present in 82.67% of cases in the right lobe of the livers. The morphology of the sulcus was classified into three Types *viz*. Type 1 describes a deep sulcus in the right lobe. This was further subdivided into Type 1A (44%), which describes the RS as a deep sulcus which was continuous medially within the hilum of the liver; Type 1B (6.67%) describes RS as a deep sulcus which was fused medially. Type 2 (25.33%) was slit-like, superficial and narrow. Type 3 describes RS as a scar, since it appeared as a fused line. RS has an average length of 3.16 cm, an average breadth of 0.1 cm and an average depth of 0.78 cm.

Since the advent of laparoscopic cholecystectomy, the incidence of bile duct injuries has steadily increased. RS has been identified as an extrabiliary landmark that may mitigate iatrogenic injuries resulting from such hepatobiliary surgeries. Therefore, a thorough understanding of the anatomy of RS is of significant importance to surgeons and hepatologists.

Key words: Rouviere's sulcus – Liver anatomy – Laparoscopic cholecystectomy – Morphology – Morphometry – Clinical anatomy

INTRODUCTION

Laparoscopic cholecystectomy was first accomplished by Professor Erich Mühe of Germany on September 12, 1985, and has today become one of the most common operations globally (Lockhart and Singh-Ranger, 2018). The most dreaded complication of this surgical procedure, which gained popularity over time, was injury to the bile ducts or hepatic arteries (Goodman and Hunter, 1991; Legorreta et al., 1993; Adamsen et al., 1997; Merrie et al., 1997; Shea et al., 1998), even when performed by experienced surgeons (Dekker and Hugh, 2008). Given the severe nature of this complication, the surgeon is required to make every effort to minimize the threat of biliary tract injury, and thus an accurate identification of the hepatobiliary anatomy is crucial in laparoscopic cholecystectomy (Galketiya et al., 2014). The greatest number of biliary injuries are believed to occur due to misidentification of biliary anatomy as a result of misinterpretation and/or a lack of understanding the anatomy (Hugh et al., 1997; Macfayden et al., 1998; Slater et al., 2002; Sicklick et al., 2005; Strasberg, 2005; Connor and Garden, 2006; Hunter and Thompson, 2006; Jarnagin and Blumgart, 2007; Wu and Linehan, 2010). The identification of anatomical structures at laparoscopy is fur-

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ther problematic, as these structures exist in a 3-D axis as opposed to the surgeon's 2-D view (Galketiya et al., 2014). In addition, the bile duct can be injured due to inflammation or infection as a result of acute cholecystitis, variant anatomy, haemorrhage and surgical inexperience (Wu and Linehan, 2010). Historically, Calot's triangle (defined as an anatomical triangle bounded by the cystic duct, the common hepatic duct and the cystic artery) has been utilized as the benchmark for the safest approach to laparoscopic cholecystectomy (Lockhart and Singh-Ranger, 2018). Another useful yet less well-recognized internal extrabiliary anatomical landmark in cholecystectomy is Rouviere's Sulcus (RS).

Rouviere's sulcus was initially described in 1924 by a French surgeon, M.H. Rouviere, who noted a fissure on the posterior surface of the liver, running transversely from the caudate process to the right lobe (Rouviere, 1924; Dahmane et al., 2013; Aoki et al., 2016).

The floor of RS usually contains branches of the right hepatic artery, right portal vein and right hepatic bile duct. RS lies in the plane of the common bile duct (CBD), giving it significance as an important anatomical landmark to guide surgeons undertaking hepatobiliary procedures, particularly cholecystectomy (Hugh et al., 1997; Zubair et al., 2009; Dahmane et al., 2013). Galketiya et al. (2014) described the sulcus as having a variable length and also presenting as being partially fused. Lockhart and Singh-Ranger (2018) further reported that the sulcus lies oblique to the anterior, inferior and external edge of the liver in 97% and horizontal in 3% of cases. Specifically, the sulcus has been reported to be a useful landmark in laparoscopic cholecystectomy (Hugh et al., 1997), as it "points" to the neck of the gallbladder (the narrow area that then tapers into the cystic duct) and can therefore be used as a reference point to expedite identification and dissection in Calot's triangle, thus safely identifying the cystic duct and artery (Lockhart and Singh-Ranger, 2018). The RS becomes easily identifiable when anterosuperior and leftward traction of the gallbladder neck are undertaken (Hugh et al., 1997; Nagral, 2005). Identification of the RS will alert the surgeon to the superior extent of the CBD; thus, dissection above the plane of the RS will contribute to avoiding CBD injuries.

Despite multiple recommendations for the use of RS as an anatomical landmark, the significance of RS remains an underappreciated facet of the surgical anatomy pertinent to effecting a safe laparoscopic cholecystectomy and right hepatectomy (Kawarada et al., 2000; Nagral, 2005; Dahmane *et al*., 2013; Singh and Prasad, 2017; Lockhart and Singh-Ranger., 2018). In addition to quantifying its frequency, this study aimed to highlight the description of the sulcus in terms of its direction and classify the sulcus based on the degree of its depth. In addition, measurements of the RS were taken (length, breadth and depth).

MATERIALS AND METHODS

This study included the gross anatomical examination of seventy-five formalin-fixed, macroscopically healthy adult livers obtained from the Discipline of Clinical Anatomy, University of KwaZulu-Natal, Durban, South Africa. The direction and type of RS was recorded following the classification system proposed by Singh and Prasad (2017). Additionally, the length, breadth and depth of RS were recorded by use of suture silk which was then extrapolated onto a standard vernier caliper to assess measurements. Given the three dimen-

Table 1. Incidence of types of Rouviere's sulcus (RS).

Author (year)	Sample Size (n)	Frequency of RS (%)	Type (%)		
			1	2	3
Rouviere (1924)	-	52	-	-	-
Gans (1955)	-	80	-	-	-
Reynaud et al. (1991)	-	73	-	-	-
Hugh et al. (1997)	100	78	-	-	-
Zubair et al. (2009)	160	68.13	30	-	38
Dahmane et al. (2013)	40	82	70	-	12
Thapa et al. (2015)	200	75	66	25	-
Kim et al. (2016)	369	75	62	12	0
Singh and Prasad (2017)	100	100	71	23	6
Al-Nazer (2018)	402	79.3	54.9	24.4	0
Present Study (2018)	**75**	**82.67**	**50.67**	**25.33**	**6.67**

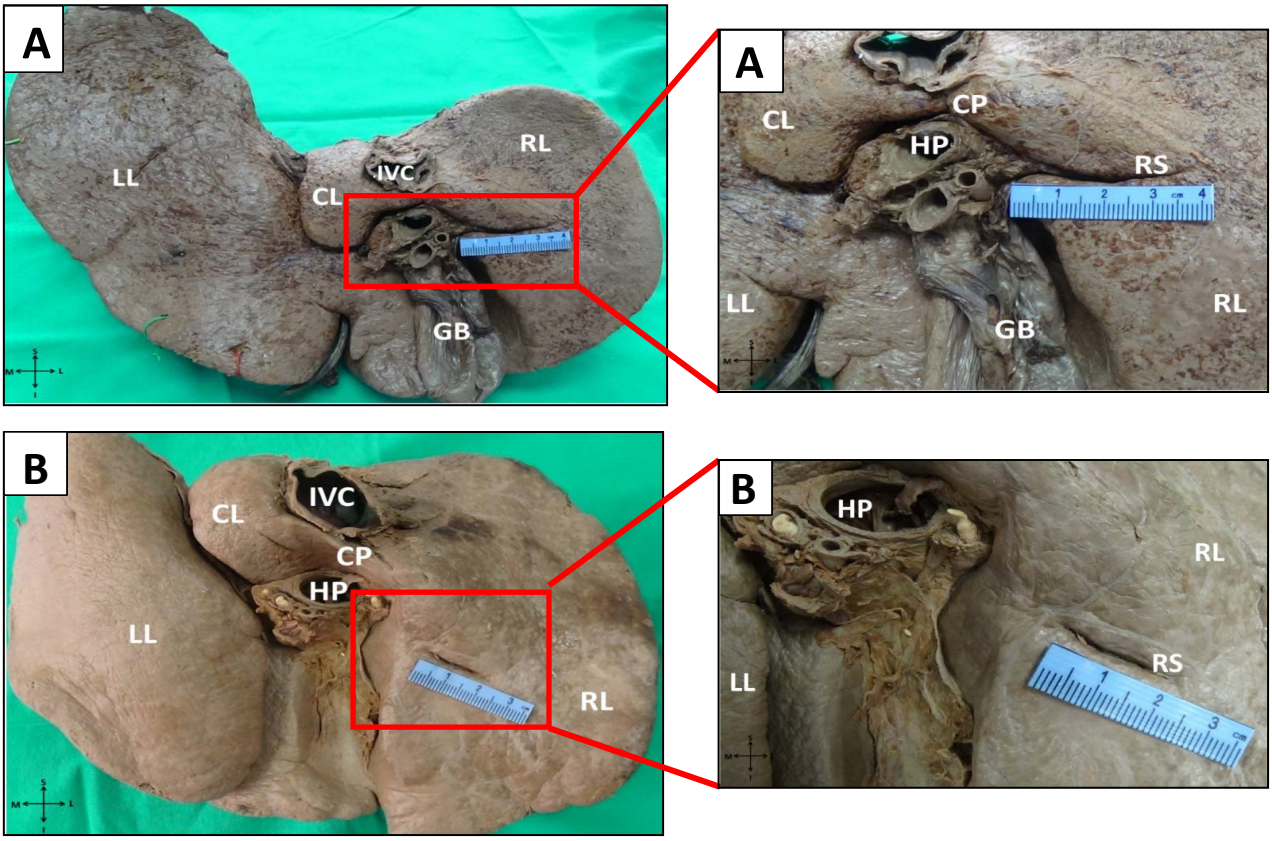

Fig 1. Type 1 of Rouviere's Sulcus: A- Type 1A: Deep open sulcus continuous medially with hilum; B- Type 1B: Deep open sulcus not continuous with hilum.

Common keys. CL- Caudate Lobe; CP- Caudate Process; GB- Gallbladder; HP- Hepatic Portal; I- Inferior; IVC-Inferior Vena Cava; L- Lateral; LL- Left Lobe; M- Medial; RL- Right Lobe; RS- Rouviere's Sulcus; S- Superior.

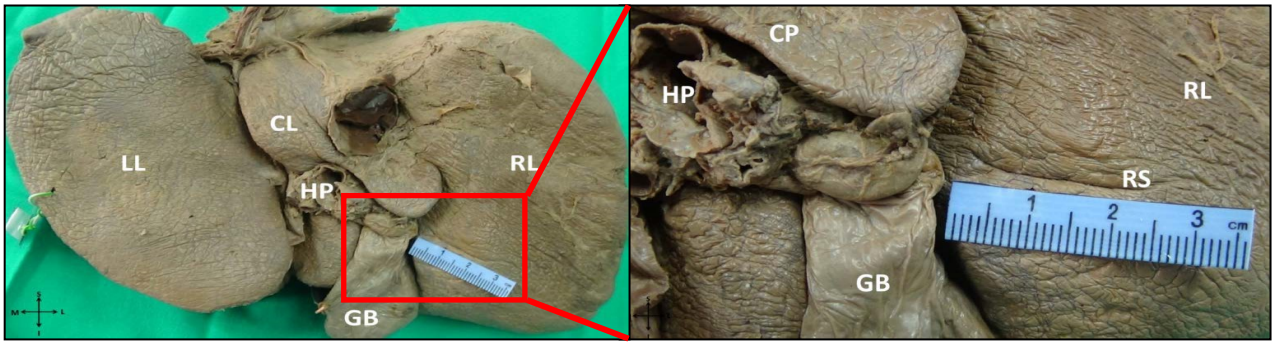

Fig 2. Type 2 – Slit type Rouviere's sulcus.

sional nature of the sulcus, the breadth and depth of the sulcus differed along its length. Therefore, measurements were taken at the medial and lateral ends of the sulcus, and at the point midway between these two points. Thereafter, an average of each measurement was calculated.

RESULTS

Out of the seventy-five livers dissected, the RS was present in 62/75 cases (82.67%) and absent in 13/75 of cases (17.33%) (Table 1).

The frequency of various types of Rouviere sulcus

This study described the RS as either Type 1, 2 or 3 based on the degree of depth into the liver tissue of the right lobe. Type 1 was described as a deep sulcus which was further subdivided into Type 1A where the sulcus was open at its medial end and was continuous with the hilum of the liver (Table 1; Fig. 1A). This was found in 33/75 (44%) cases. Type 1B was described as a deep fissure that appeared closed on the medial end due to the fusion of liver parenchyma at that point (Table 1; Figure 1B). This was found in 5/75 (6.67%) of cases studied. Type 2 RS was defined as a slit-like, superficial, narrow sulcus (Table 1; Fig. 2) which occurred in 19/75 (25.33%) of the specimens investigated. Type 3 was observed to be a scar-like, white line where the parenchyma appeared to have fused (Table 1; Fig. 3). This type occurred in 5/75

Table 2. Incidence of direction of Rouviere's sulcus

Author (year)	Sample Size (n)	Direction (%)		
		Horizontal	Oblique	Vertical
Dahmane et al. (2013)	40	3	97	0
Singh and Prasad (2017)	100	70	31	2
Present Study (2017)	75	41.33	41.33	0

Table 3. Morphometry of Rouviere's sulcus.

Author (year)	Sample Size (n)	Mean Length (cm)	Mean Breadth (cm)	Mean Depth (cm)
Dahmane et al. (2013)	40	2.8	-	0.6
Singh and Prasad (2017)	100	2.03	0.97	0.96
Present Study (2017)	75	3.16	0.16	0.78

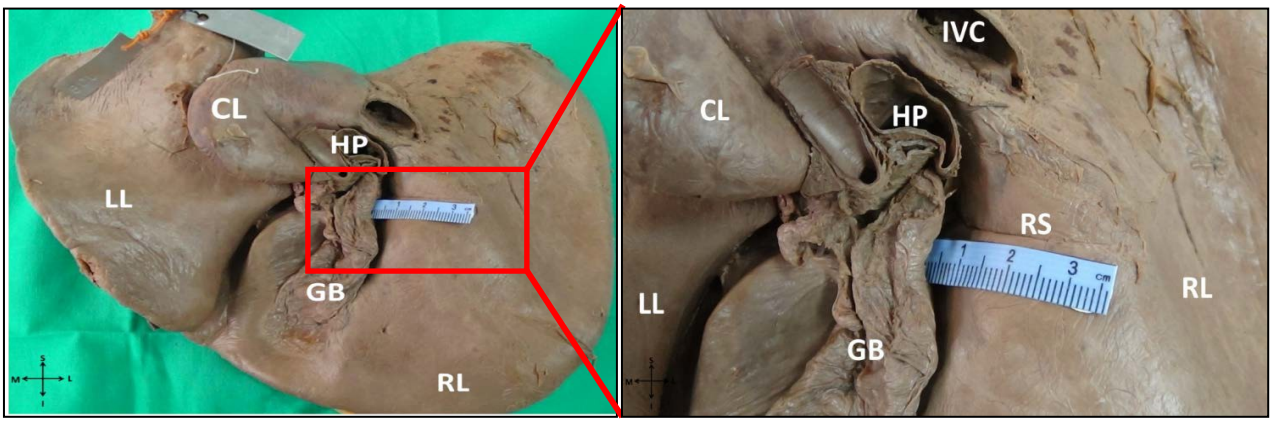

Fig 3. Type 3 – Scar type of Rouviere's sulcus.

(6.67%) of the livers dissected.

Direction of sulcus/ slit/ scar

The direction of the sulcus in its various forms was equally horizontal in 31/75 of cases and oblique as depicted in Table 2 and Fig. 4.

RS was identified as either oblique (41.33%) or horizontal (41.33%) to the superior and inferior border of the liver (Table 2; Figs. 4A and 4B).

Measurements of the sulcus

In the slit and scar type of sulci, only the length was measured, while in the deep sulcus all three dimensions (length, breadth and depth) were measured. The average length of RS was 3.16cm (Table 3) extending from the porta hepatis all the way to its termination in the right lobe of the liver. The average breadth of RS was 0.16cm (Table 3). The average breadth was 0.23cm at the medial end of the sulcus, 0.15cm at the midpoint and 0.09cm at the lateral end of the sulcus. The average depth of RS was 0.78cm (Table 3). The average depth was 1.05cm at the medial end of the sulcus, 0.90cm at the midpoint and 0.41cm at the lateral end of the sulcus.

DISCUSSION

Historical Background and Terminology

In the surgical and anatomical literature, there are several names that are used to depict the RS (Dahmane et al., 2013). In 1924, the French surgeon MH Rouviere first described a transverse fissure on the right lobe of the liver, anterior to the caudate process, with the right branch of the portal vein lying in its floor (Galketiya et al., 2014). A couple of decades later, Gans also described this sulcus as an extension of the porta hepatis and called it 'incisura dextra' (Galketiya et al., 2014; Singh and Prasad, 2017). Later studies adopted the term 'Rouviere's Sulcus', except Reynaud et al. who referred to the sulcus as 'incisura dextra of Gans' (Galketiya et al., 2014). However, after a review of the literature, the present study noticed the irregular nomenclature of RS in recent studies, referring to RS as either the 'accessory inferior sulcus of the liver' or 'an accessory sulcus of the liver' (Muktyaz et al., 2013; Cawich et al., 2016). In addition, the sulcus is given little recognition in operative textbooks (Galketiya et al., 2014). It is therefore imperative that a detailed anatomy of the RS is acknowledged so that clinicians and researchers may be aware of the terminology regarding this structure and thereafter become aware of its clinical significance, as it is a useful adjunct in the prevention of biliary injuries.

Morphology

The present study incorporated terminology regarding the morphology of RS as proposed by Singh and Prasad (2017) and classified these descriptions as Type 1-3.

The direction of the sulcus was found to be either oblique or horizontal to the superior and inferior border of the liver. The oblique direction was observed in 31/75 (41.33%) of specimens (Table 2;

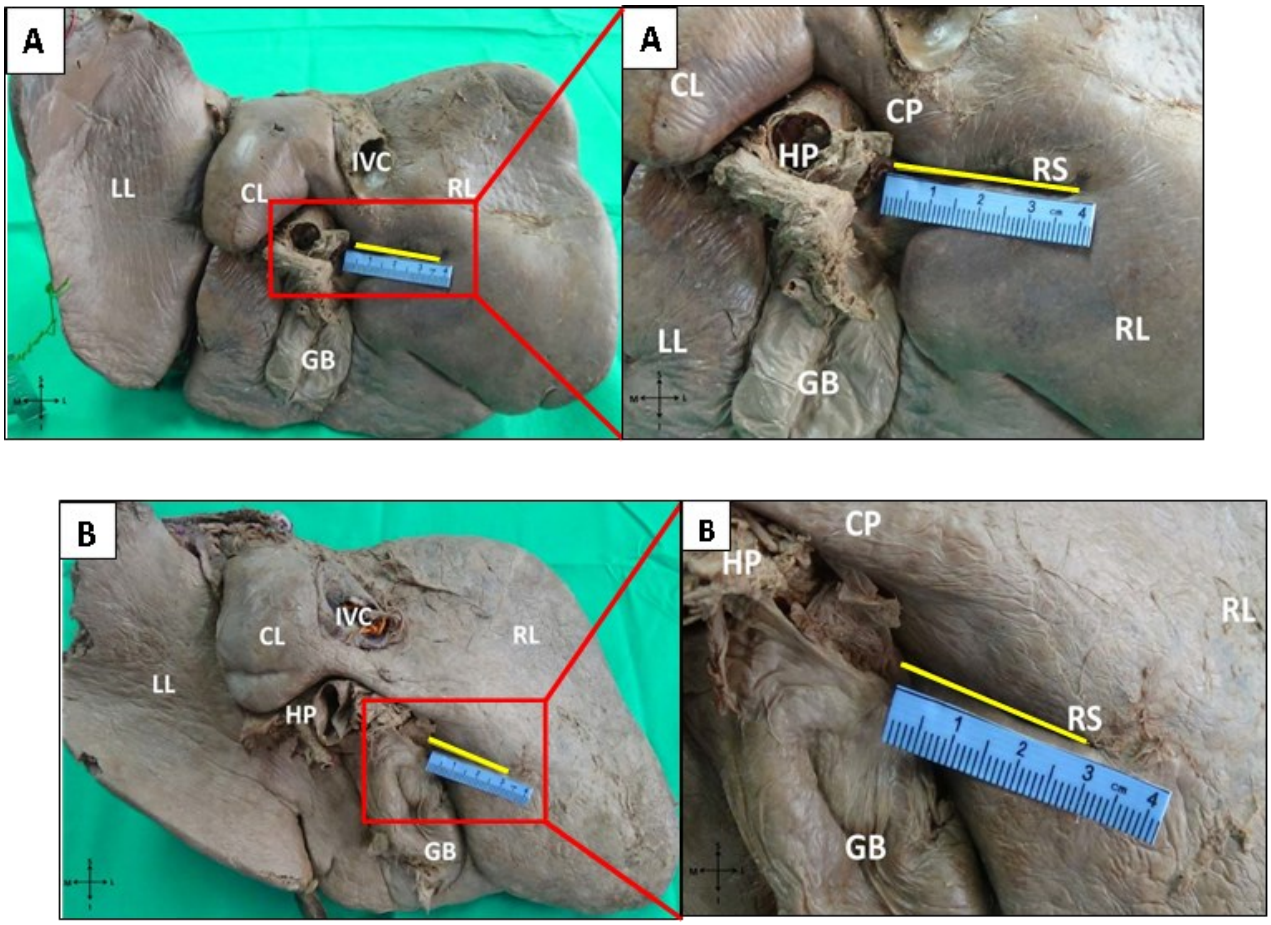

Fig 4. Direction of Rouviere's sulcus (yellow line). A- horizontal; B- oblique

Fig. 4B). This is significantly lower than the findings of Dahmane et al. (2013) who observed this in 97% of cases. However, Singh and Prasad (2017) only found this in 31% of cases (Table 2). In the present study, RS was found to have a horizontal direction in 31/75 (41.33%) of specimens, which was higher than the finding of Dahmane et al. (2013) who only observed this in 3%, whereas Singh and Prasad (2017) noted horizontal RS in 70% of cases (Table 2; Fig. 4A). The direction of RS may have an important application in laparoscopic cholecystectomy. Since this sulcus lies on the plane of the common bile duct, a line extrapolated from RS, across porta hepatis indicates a surgical 'safe-zone' ventral to the imaginary line (Galketiya et al., 2014). It is well agreed that the usage of RS as an extra biliary anatomical landmark may decrease the incidence of CBD injury (Nagral, 2005; Zubair et al., 2009; Galketiya et al., 2014; Singh and Prasad, 2017). Additionally, Nagral (2005) in a study of anatomy relating to cholecystectomy explained that such injuries cause significant morbidity and are a common cause of litigation against surgeons.

Singh and Prasad (2017) proposed 3 terms to describe RS: deep sulcus, slit and scar. The present study classified these terms as Types 1 to 3.

Type 1A described a deep sulcus which was 'open' at its medial end and was continuous with the porta hepatis (Table 1; Fig. 1A). This was found in 33/75 (44%) of liver specimens in the present study, which is in line with the findings of Thapa (2015) and Singh and Prasad (2017) who observed this in 51% and 60%, respectively (Table 1). Type 1B was a deep sulcus that was 'closed' at the medial end as the liver parenchyma was fused (Table 1; Fig. 1B). This only occurred in 5/75 (6.67%) specimens in the current study. Similarly, Thapa (2015) only observed this in 12% and Singh and Prasad (2017) in 11%.

Type 2 describes RS sulcus as a slit, as it was narrow and very shallow (Fig. 2). Type 2 occurred in 19/75 (25.33%) of cases. This outcome correlated with that of Thapa (2015) and Singh and Prasad (2017) who recorded Type 2 in 25% and 23% respectively (Table 1).

Type 3 describes RS as a scar, since it appears as a 'line of fusion' where the liver parenchyma is fused and a white line is visible (Fig. 3). The present study found Type 3 in only 5/75 (6.67%) of cases, which is similar to the finding of Dahmane et al. (2013) and Singh and Prasad (2017) who observed this in 12% and 6%, respectively (Table 1). However, Zubair et al. (2009) recorded the scar like RS in 38%, which was significantly higher than the findings of this study (Table 1). Knowledge of the frequencies of the various types of RS is essential for the accurate identification of the sulcus during

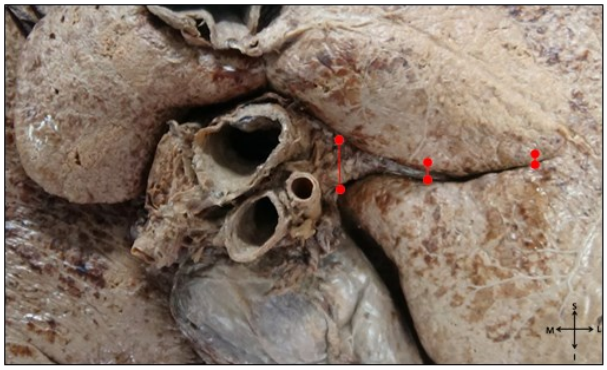

Fig 5. Rouviere's sulcus with markers depicting the points of measurement (red arrows) of breadth at the medial, middle and lateral end of the sulcus.

surgeries.

Morphometry

There is a noticeable paucity of literature regarding the morphometry of RS. This may be due to the fact that much of the recent literature on RS has been conducted on patients during laparoscopic procedures which did not allow for measurements to be taken. The average length of RS in the present study was 3.16 cm (Table 3). This measurement was slightly longer than that of Dahmane et al. (2013) (2.8 cm) and Singh and Prasad (2017) (2.03 cm) (Table 3). The breadth of RS differed at various points (Fig. 5). The medial end of the sulcus was generally the widest and had an average measurement of 0.23 cm, the midpoint was 0.15 cm on average and the lateral end was 0.09 cm. The average breadth of RS in this study was 0.16 cm, which was significantly narrower than the finding of Singh and Prasad (2017), who recorded an average breadth of 0.97 cm (Table 3). The depth of the sulcus also differed at various points; at the medial end RS was found to be the deepest with an average depth of 1.05 cm. At the midpoint the average depth was 0.9cm and at the lateral end the sulcus was 0.41 cm deep on average. The average depth of RS in this study was 0.78 cm, which is in line with the finding of Dahmane et al. (2013) (0.6cm) and Singh and Prasad (2017) (0.96cm) (Table 3).

Limitations

Excessive traction of the gallbladder fundus superiorly or inflammation and adhesion may lead to distortion of anatomical structures that could mislead the surgeon if too much emphasis is placed on this landmark. Notwithstanding the value of RS as a surgical landmark, its demonstration may also not be consistent in situations such as extensive gallbladder disease scarring, cirrhosis of the liver and fatty disease of the liver. The key to avoiding bile duct injuries is surgical caution, adequate training, the use of multiple anatomical landmarks and an appreciation of the variability of the anatomy of the area (Galketiya et al., 2014).

CONCLUSION

In the current era of minimally invasive surgery, an accurate knowledge of the anatomy of the RS as an extra-biliary landmark may be essential to mitigate the risk of iatrogenic injury during laparoscopic cholecystectomy and right hepatectomy (Fig. 6). The relatively easy appreciation of this constant anatomical feature makes the RS a dependable landmark during severe acute inflammation when the surgeon must dissect ventral to the sulcus to ensure that he/she operates away from the danger area of Calot's triangle. Therefore, the RS is a valuable additional landmark to the surgeon's anatomical armamentarium.

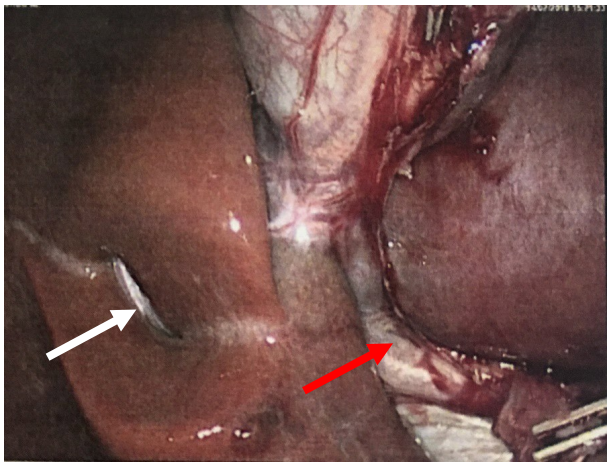

Fig 6. Demonstration of Rouviere's sulcus (white arrow) at laparoscopic cholecystectomy and superior aspect of common bile duct (red arrow).

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